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SPACE-CHARGE LIMITS ON THE TRANSPORT OF ION BEAMS IN A LONG ALTERNATING GRADIENT SYSTEM*

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Abstract

We have experimentally studied the space-charge-dominated transport of ion beams in an alternating-gradient channel, without acceleration. We parameterize the focusing strength in terms of the zero-current "betatron" oscillation phase advance rate, σ_0 (degrees per focusing period). We have investigated the conditions for "stability", defined as the constancy of the total current and phase space area of the beam during transport. We find that the beam may be transported with neither loss of current nor growth in phase area if $\sigma_0 < 90°$. In this regime, the space-charge repulsive force can counter 98–99% of the externally applied focusing field, and the oscillation frequency of the beam particles can be depressed by self-forces to almost a factor of 10 below the zero-current value, limited only by the optical quality of our ion source. For $\sigma_0 > 90°$, we find that collective interactions bound the maintainable density of the beam, and we present a simple, semi-empirical characterization for stability, within our ability to distinguish the growth rate from zero in our apparatus. Our channel comprises 87 quadrupole lenses, 5 of which are used to prepare the beam for injection into the non-azimuthally-symmetric focusing channel.

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